GRAVITY RESEARCH OF THE DEEP STRUCTURE OF HUNGARY

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ZUSAMMENFASSUNG

Die seismischen Messungen auf dem Gebiete von Ungarn haben die Verdünnung der Erdkruste festgestellt. Diese Abhandlung untersucht, inwieweit sich die Verdünnung der Erdkruste in den Ergebnissen der ungarischen gravimetrischen Messungen offenbart.

Die gravimetrischen Messungen in Ungarn zeigen hauptsächlich zwei Wirkungen: einerseits die Wirkung der lockeren tertiären Schichten von der Mächtigkeit von einigen Kilometern mit geringer Dichte, anderseits die Wirkung der verdünnten Erdkruste. Um die Wirkung der Krustenstruktur auf der gravimetrischen Karte zu erhalten, muss man die Wirkung der Sedimente nahe der Oberfläche beseitigen. Dies kann auf folgende Weise geschehen.

Die Dichte der lockeren Sedimente wächst mit der Tiefe und kann gemäss der folgenden Beziehungen angenähert werden:

$$\sigma_z = \sigma_0 + (\sigma_\infty - \sigma_0)(1 - e^{-kz})$$

Hier bedeutet σ die Dichte, die Indices 0,z, ∞ deuten auf die Tiefe hin, k ist eine Konstante. Die Werte von k wurden auf verschiedenen Gebieten des Landes mit Hilfe der Bouguer-Anomalien und auf Grund der Tiefenkarte der tertiären Sedimente mit Korrelationsrechnung ermittelt. Mit guter Annäherung ist $\sigma_0 = 2{,}05$, $\sigma_\infty = 2{,}85$ cgs.

Die Gravitationswirkung ist durch die Annäherung der Bouguer-Platte gegeben:

$$\Delta g' = 2\pi f h \left\{ \sigma_\infty - \frac{1}{h} \int_0^h [\sigma_0 + (\sigma_\infty - \sigma_0)(1 - e^{-kz})] dz \right\}$$

Die beigefügte Anomaliekarte wurde so verfertigt, dass wir auf den Stationen des Schweregrundnetzes die den Tiefen des Beckens entsprechenden Korrektionen zu den gemessenen Bouguer-Anomalien addierten.

Die so erhaltene Karte ist von der Wirkung der Sedimente befreit und zeigt die Gebilde der Tiefstruktur.

Seismic investigations have demonstrated the peculiar structure and thinning-out of the Earth's crust in the Hungarian area. This paper investigates the gravity effect of the thinning-out of the Earth's crust.

The Bouguer-anomaly map constructed on the basis of the I. and II. order gravimetrical base network of Hungary is shown in Fig. 1.

The structure of the Earth's crust cannot be determined directly and exactly out of gravity anomalies. Seismical measurement is used first for this. It is a fact, however, that the thinning-out of the Hungarian crust is even

Fig. 1. Bouguer-anomalies.

demonstrated by the positiveness of the Hungarian Bouguer-anomalies (e. g. as compared to the close orogenic mountains.)

The deep-seated lateral density-variations – contributing to the Hungarian Bouguer-anomaly – are, as follows:

1. the density-variation of Tertiary basin sediment (with or without structure).

2. the horizontal density-variation of the basement (with or without change in topography or lithology).

3. the mantle – higher up owing to a thin crust – as a whole (as a regional tendency) and its topography.

Our present examinations refer to this last effect taking into consideration, that the effects become increasingly vague and regional with increasing distance from the surface.

The gravity-map must be exempted from the gravity-effect of young basin sediments, for getting the effect of the Earth's crust structure. This can be realized as follows: the topography and lithology of the Mesozoic-Paleozoic basement are known generally from drilling and seismical measurements in the Hungarian area. Knowing the density of sediments and basement, the loose sediment can be replaced in thought with the material of the consolidated basement.

The average density of the basement was found to be 2,85 cgs by examining many drill-cores. The average density of the sediment-complex in the basement is 2,05 cgs reduced to sea-level altitude. The problem is, that the density of loose sediment increases considerably with the depth, but in a different way in each area.

The density increase depending on depth may be approximated by an exponential function.

The density in depth z is

$$\sigma_z = \sigma_0 + (\sigma_\infty - \sigma_0)(1 - e^{-kz})$$

$\sigma_0 = 2{,}05$ cgs is the density of surface, $\sigma_\infty = 2{,}85$ cgs is the density at great depth. In this approximation the sole parameter of the density-depth function is the exponent k. The above mentioned relation is to be found in Athy's paper and it is valid mostly for clayey sediment [1]. It may be extended approximatively to the clayey-sandly-marly complex of the Hungarian basement.

The exponential factor k may be determined out of the Bouguer anomaly, knowing the topography of the basement. The change of the Bouguer-anomaly correlates at many points with the depth of basement. (Ádám, Pintér, Szénás 1964.) In such points the smaller values of Bouguer-anomaly are indicative of the sinking of the basement to some depth. The correlation between the depth of the basement and the values of the Bouguer-anomaly offers a possibility to determine the density relations of the sediment complex of the basement.

The topography of the basement is demonstrated by a map constructed by L. Kőrössy [2] (Fig. 2.) Dividing the country's area into several regions, the Bouguer-anomaly's dependence on the depth of basement has been examined separately in each region. The relation shown in Fig. 3. is referring to south-

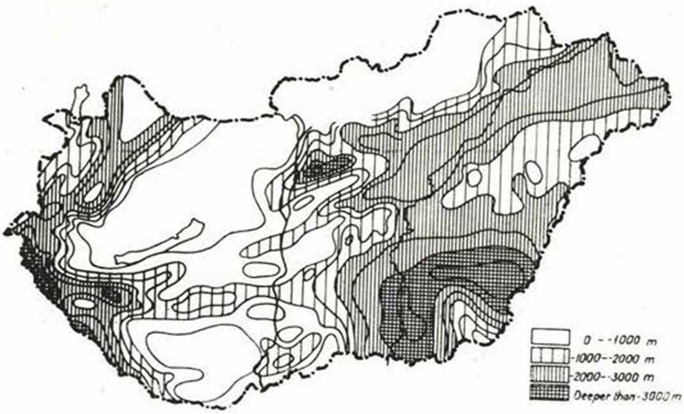

Fig. 2. Isohypses of the basement.

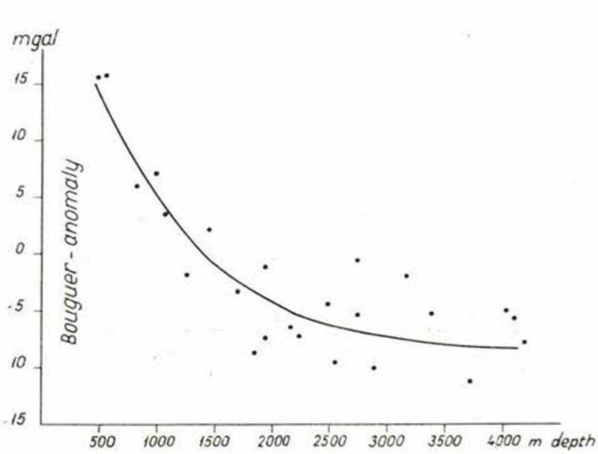

Fig. 3. Variation of Bouguer-anomalies with depth in South-west Transdanubia.

west Transdanubia. The best-fitting compensated curve has been traced among the points. The dispersion of effectively measured Bouguer-anomalies with respect to the compensated curve is rather small. With the help of the compensated curve one Bouguer-anomaly value has been assigned to each depth interval of 100 m. It has been named the graphically compensated Bouguer-anomaly.

The further purpose of our computation was to determine for a given depth the gravitational effect due to substituting the real sediment complex by non-consolidated basement rocks, up to the sea-level. In this computation the density change with depth had to be considered. The density-variation is given by the above mentioned exponential relation: the average density for depth h is

$$\overline{\sigma}_h = \sigma_0 + (\sigma_\infty - \sigma_0)\frac{1}{h}\int_0^h (1-e^{-kz})dz = \sigma_\infty - (\sigma_\infty - \sigma_0)\frac{1}{kh}(1-e^{-kh}).$$

Substituting the sediment for non-porous rock of the basement the density difference $\sigma_\infty - \overline{\sigma}_h$ must be reckoned. From the above,

$$\sigma_\infty - \overline{\sigma}_h = (\sigma_\infty - \sigma_0)\frac{1}{kh}(1-e^{-kh}).$$

The effect is computed as the effect of a Bouguer-plate of density $\sigma_\infty - \overline{\sigma}_h$ and thickness h; the correction is

$$\Delta g' = 2\pi f(\sigma_\infty - \sigma_0)\frac{1}{k}(1-e^{-kh}) \text{ mgal}.$$

The Δg' correction has been computed for the following values of k:

$$10^6 \cdot \mathrm{k} = 5{,}8;\ 8;\ 9;\ 10;\ 11;\ 12;\ 13;\ 17{,}3.$$

Adding to the graphical compensated Bouguer-anomaly the Δg' correction, Δg'' values were obtained which exhibited different trends in function of depth for different k factors. In the area illustrated for an example (Fig. 4.). the

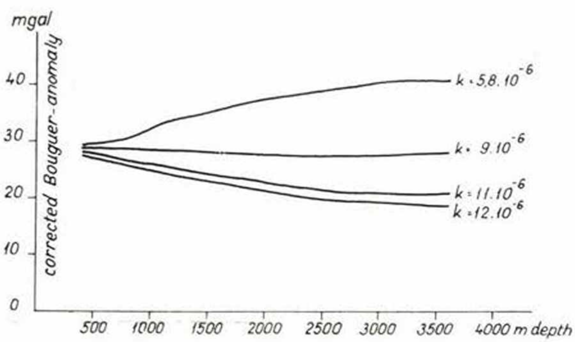

Fig. 4. Variation of corrected Bouguer-anomalies with depth in south-west Transdanubia.

$\Delta g''$ anomaly shows an increasing trend with $k = 5{,}8 \cdot 10^{-6}$ and a decreasing trend with $k = 12 \cdot 10^{-6}$, the curve being parallel to the depth axis for $k = 9 \cdot 10^{-6}$. It is consequently in this latter case that the corrected anomaly is independent from depth. Density-variation given by this valne of k best approximates reality.

Using the same method, different k values are found generally in each region. The determination of these has been accomplished for the following regions.

Region	$10^6 \cdot k$
South-west Transdanubia	9
Little Hungarian plain	9
Area of Bakony Mountains	5,8
Somogy-County	9
Baranya-County	11
Fejér-Tolna County	10
Komárom County, Vértes Mountains	11
Northern part of the territory between the rivers Duna – Tisza	11
Southern part of the territory between the rivers Duna – Tisza	12
Heves County	12
Northern part of Pest county	12
Borsod County	10
Hajdú County	8
Szolnok-Bihar	8

This method could not be applied, in absence of correlation, to the south and north-east area of the territory east of Tisza river. In the southern smaller area of this territory (around Tótkomlós), however, a suitable correlation can be found with detailed gravity-data, and by reason of this the k value could be determined.

In areas where no suitable correlation between the basement topography and Bouguer-anomaly can be found, the k value has been interpolated from nearby data, therefore in these places the source of the corrected Bouguer-anomaly is less certain.

According to the above said, the computing of the topographic effect of the sediment-complex has been performed by the Bouguer-plate approximation. To get a more correct result, it would be necessary to apply the topographic formula to the basement topography. This more accurate computing has been accomplished for 50 base-network points in the area between the rivers Duna – Tisza. In many cases these values differed by less than 1 mgal from the results of the simpler computing, by the Bouguer-plate, and the difference naturally had positive values in the higher basement areas and negative values in the lower ones. The difference is shown in Fig. 5. as a function of depth. With this method we get a more correct approximation than in the case of the Bouguer-plate.

Inspecting the distribution of the k factor in the country the lines of equal k values can be traced. (Fig. 6.) In a country-wide relation the smaller values of k are to be found in the area where the sediment-complex is thicker. (Little

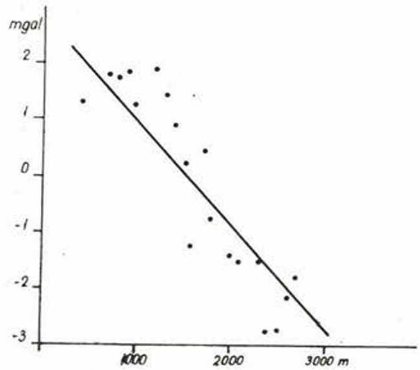

Fig. 5. Topographical corrections of Bouguer-plate.

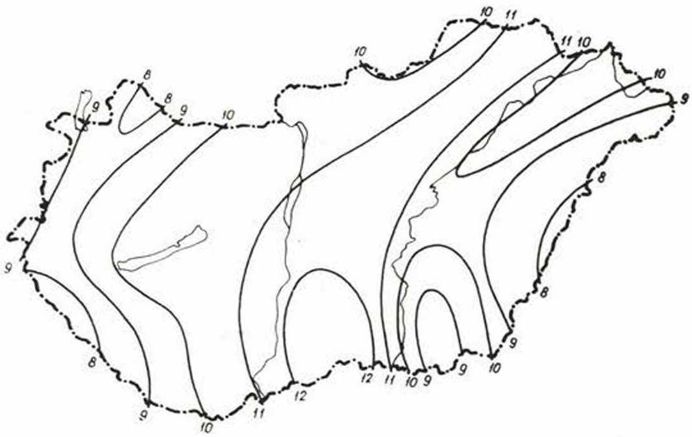

Fig. 6. Lines of equal values of k.

Hungarian plain, Zala County). In hilly country the basement is on the surface, wherefore this method is useless. In these places the base-network points of the Bouguer-anomaly have not been corrected.

Finally a characteristic k value has been assigned to every base-network point of the country and the $\Delta g'$ correction has been computed. The $\Delta g''$ anomaly corrected by this method is supposed to be exempt of the effect of the sediment complex. Considering the basement as approximatively homogeneous, these anomalies represent the regional effect of the deep structure. (Fig. 7.) Where the regional effect is greater, the Earth's crust is necessarily thinner, because the compact rocks of the crust are nearer to sea-level. The value of the corrected anomaly is about + 30 mgal on an average in the Hungarian area. This value decreases to 10 – 20 mgal close to the Alps and in the north-east close to the Carpathians which can indicate a relative thickening of crust. [3].

Our computations were completed by the averaging of the values obtained for 3 – 4 neighbouring points of the gravity base network, in order to find out average trends. (Fig. 8.) There is small difference between the two images.

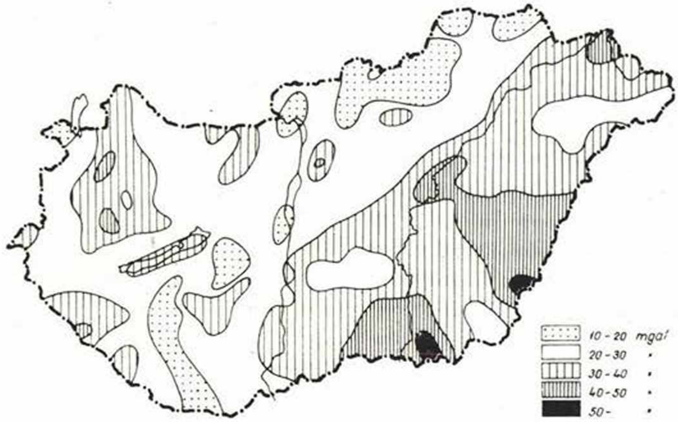

Fig. 7. Corrected Bouguer-anomalies ($\Delta g''$).

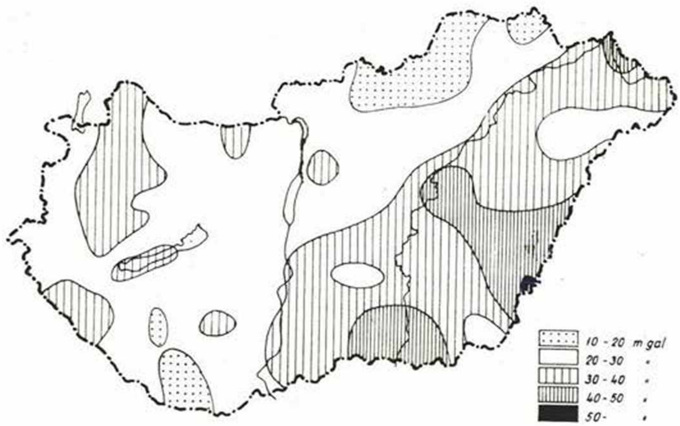

Fig. 8. Averages of corrected Bouguer-anomalies ($\Delta g''$).

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